A Synopsis on

PERFORMANCE EVALUATION AND EMISSION CHARACTERISTICS OF CI ENGINE BY USING BIODIESEL WITH NANOPARTICLES AS AN ADDITIVE

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TITLE OF THE THESIS

Performance Evaluation and Emission Characteristics of CI Engine by Using Biodiesel with Nanoparticles as an Additive

INTRODUCTION

The global population and manufacturing sector is expanding rapidly in response to the increasing energy needs. Fossil fuels are the primary energy source for commercial and industrial applications. Coal, natural gas, and petroleum oils are primary fossil fuels. Traditional fuels fulfill two-thirds of the world's energy needs. India having the second-largest population in the world. India's rapidly growing energy needs is significant global issue. Coal remains the primary energy source for 1.36 billion people. This energy demand is expected to rise by 28% between 2015 and 2050.

Fossil fuel depletion and toxic emission are global concern. Compression ignition engines contribute to toxic emissions. It is advised to use exhaust gas treatment equipment, combustion improvement techniques, and engine design modifications to lower emissions. Volatile organic compounds (VOCs) from incomplete combustion and unburned fuel emissions are the main constituents of engine exhaust, which are harmful to human health and are primarily found in gasoline and diesel-powered cars. Conventional fuel’s finite supply and greenhouse gas emissions have led to efforts to find ecofriendly substitutes.

Alternative fuels like biodiesel, natural gas, ethanol, and hydrogen are being explored to meet energy demands without causing further global warming. Biodiesel, derived from renewable resources like biomass, is being explored as alternative fuel. Biofuels are fuels produced through modern organic cycles, such as agribusiness and anaerobic assimilation, rather than topographical cycles. They can be obtained directly from plants, agriculture, industry, domestic production, or waste products. Sustainable biofuels are primarily derived from sources that utilize photosynthesis such as plants or microalgae. Biofuels like biodiesel and alcohol are being explored to reduce diesel fuel consumption and emissions.

STATEMENT OF THE RESEARCH PROBLEM

The growing need for sustainable energy solutions and environmental protection makes it imperative to explore alternative fuels for diesel engines. Biodiesel holds promising benefits, including enhanced engine performance and reduced exhaust emissions, however, its effectiveness is restricted by challenges such as a lower cetane number, high ignition

temperature, and other thermo-physical constraints. Recent progress indicated that the addition of nanoparticles, particularly graphene nanoplatelets (GNPs) into biodiesel blends can address these challenges, due to its superior thermophysical properties help in biodiesel atomization and heat distribution during combustion. However, the specific impact of GNPs in biodiesel blends on engine performance and emissions requires comprehensive investigation. This research aims to address this problem by investigating the impact of nanoparticle-blended biodiesel on diesel engine performance and emissions.

RESEARCH OBJECTIVES

An extensive literature review on the current research topic explores numerous research directions to examine the impact of GNP nanoparticles and biodiesel blends on diesel engines. The principal objectives of the proposed research work include:

1. To investigate the effect of nano-particle blended bio-diesel on diesel engine performance characteristics.

2. To evaluate the impact of nano-particle blended bio-diesel on diesel engine emission characteristics.
3. To develop regression model for predicting the impact of nanoparticle-blended biodiesel on diesel engine performance and emissions.
4. To identify and validate the optimal blend of nano-particle and bio-diesel.

NATURE AND SCOPE OF THE WORK DONE

The nature and scope of research involve a detailed experimental and analytical study to investigate the effect of incorporating nanoparticles into biodiesel fuel for emissions control in diesel engines. This work encompassed the following activities:
1. Literature review: a compressive review of existing studies done on biodiesel blended with nanoparticles to assess their combined effect on diesel engine performance parameters.
2. Nanoparticle selection and preparation: identified and prepared suitable nanoparticles based on their properties and potential effectiveness in reducing emissions.
3. Biodiesel preparation and blend formation: developed biodiesel blends with different blend ratios and concentrations of nanoparticles. Prepared biodiesel thermophysical properties were measured to ensure quality and accurate experimental results.

4. Engine testing, data collection and analysis conducted on the diesel engine test setup to measure emissions and performance parameters of each nanoparticle-charged biodiesel blend. The emissions and engine metrics were recorded for each blend. The recorded data was used to identify trends, correlations, and optimal blend formulations.

5. Comparative Analysis: The performance of nanoparticle-charged biodiesel compared with conventional diesel and pure biodiesel with nanoparticles.

6. Recommendations and future work: recommendations were provided for practical application in this section and identified gray areas for further research based on the findings.

RESEARCH METHODOLOGY

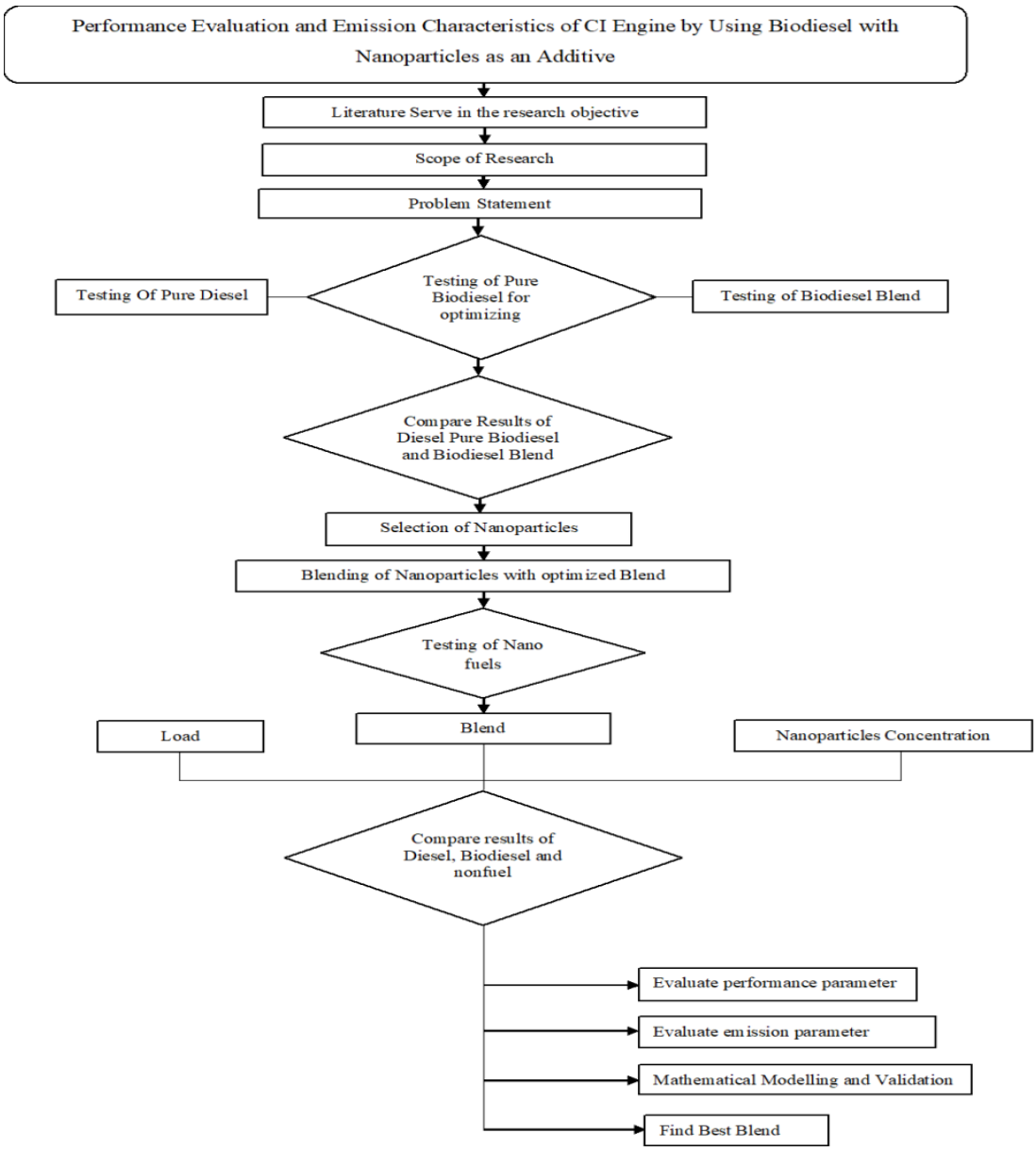
Performance Evaluation and Emission Characteristics of CI Engine by Using Biodiesel with Nanoparticles as an Additive
Literature Serve in the research objective
Scope of Research
Problem Statement
Testing Of Pure Diesel
Testing of Pure Biodiesel for optimizing
Testing of Biodiesel Blend
Compare Results of Diesel Pure Biodiesel and Biodiesel Blend
Selection of Nanoparticles
Blending of Nanoparticles with optimized Blend
Testing of Nano fuels
Load
Blend
Nanoparticles Concentration
Compare results of Diesel, Biodiesel and nonfuel
Evaluate performance parameter
Evaluate emission parameter
Mathematical Modelling and Validation
Find Best Blend

Fig. 1 Research methodology

From soybean feedstock combined with graphene nanoplatelets. Biodiesel is a renewable and biodegradable fuel derived from natural sources. The study considered cost, yield, availability, thermophysical characteristics, and economic factors when choosing biodiesel. These factors make soybean biodiesel a viable, sustainable, and economically attractive option for both experimentation and commercial use in diesel engines. The use of soybean oil for biodiesel has been encouraged by the National Biodiesel Board and the United Soybean Board. IS 15607 standards are used while selecting biodiesel. Studies have shown that using direct vegetable oil, especially soybean oil, results in carbon deposits and reduces engine life. Graphene nanoplatelets are a promising material for improving engine performance and emission traits in terms of carbon deposits. They are composed of a single hexagonal layer of carbon atoms and have a high surface area and thermal conductivity. Graphene family nanoparticles act as effective catalysts for converting triglycerides from vegetable oils or animal fats to biodiesel. The GNP nanoparticle presence in biodiesel act as catalyst during combustion and improved biodiesel thermophysical properties. The study aimed to investigate the effect of operational conditions on the diesel engine performance, including load, biodiesel blend, and GNP nanoparticle concentration. The load, blend ratio, and GNP concentration are selected as input parameters because background literature, fuel combustion chemistry, and previous studies preached this parameter directly influences engine performance, efficiency, and emissions. The engine's power was assessed under different load (3-12kg) conditions, with 3 kg representing 25% of the total load. The selected load rage evaluates engine performance under various operating conditions, which simulate real-world driving scenarios. The study also examined the preparation of soybean biodiesel through transesterification, a chemical reaction between soybean oil and alcohol. The process involved heating an oil-filled conical flask, dissolving pelletized potassium hydroxide in CH_3OH, and heating the mixture to a consistent temperature. The biodiesel was then separated from the glycerol, and the amount of biodiesel generated was calculated. Graphene nanoplatelets at 50, 75, and 100 parts per million (ppm) weight percent in biodiesel and pure diesel, and soybean volume percentages D100, B20, B30, and B40 represent tested blends B20, B20GNP50, B20GNP75, and B20GNP100 and similarly for B30 and B40.The thermophysical properties of biodiesel blend were tested considering ASTM standards.

This study evaluates four-stroke, single-cylinder diesel engine performance parameters. The engine is connected to an electric loading device and an engine-type thermocouple to measure exhaust gas temperature. Pressure transducer measures cylinder pressure, and ignition delay

measures heat release rate. The AVL Digas 444 EGA is used to measure emission parameters. The commercial single cylinder diesel engine was running at 1500 rpm with an 18:1 compression ratio. The load is changed in 25% increments from 0% to 100% throughout the trial. Blends of D100, B20, B30, and B40 are tested again, with and without adding GNPs at 50, 75, and 100 ppm concentrations. Repeat readings for the same blends are carried out to verify the accuracy of the findings. The engine runs continuously for 30 minutes for each load. The data acquisition system records various performance parameters. A full factorial design used because present study deals with less number of factors and levels. It test every possible combination of the levels of all factors included in the experiment. Orthogonal array (OA) design with 4 levels and 3 parameters to access brake thermal efficiency (BTE), brake-specific fuel consumption (BSFC), carbon monoxide (CO), carbon dioxide emission (CO_2), unburnt hydrocarbon (HC), and oxides of nitrogen emission (NOx ppm) were obtained. Mathematical modelling of each response variable was performed using regression analysis. The probability (p-value) represents significant factors. Regression coefficients of each model considered to check model accuracy. Artificial neural network (ANN) is a powerful tool to predict engine performance, and emissions characteristics. The input variables are engine load and biodiesel percentage and blend ratio and output variables like BSFC, BTE, HC, CO, NOx, and smoke emissions to predict engine performance. The number of hidden layer and neurons are identified through number of iterations. The hidden layers introduce non-linearity through activation functions, allowing the network to model more intricate and abstract patterns. The ANN model is developed using feed-forward back propagation network, and learning function. The input parameter dataset is normalized before training, and the Levenberg Marquardt training algorithm is used to create a back-propagation learning algorithm.

CONTRIBUTION TO EXISTING KNOWLEDGE

We explore the findings based on tests conducted on diesel engine with different blend ratios, GNP concentrations, and loading conditions. Following contribution made to existing knowledge. These findings contribute to sustainable development by promoting environmentally friendly energy sources.

- Investigate the performance characteristics of diesel engine using GNP nanoparticle
- The improved thermophysical and catalytic properties of graphene contribute to better fuel atomization and faster combustion, results in enhancement in BTE, reduction in BSFC.

- Graphene nanoparticles can lower harmful emissions such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM) by facilitating more complete oxidation of the fuel.
- The regression models develop to predict performance and emission characteristics having accuracy greater than 90%. ANN models meticulously validate experimental results.
- The B30GNP50 blend shows a 69.26% enhancement in brake thermal efficiency (BTE) and a reduction of 2.56% in break-specific fuel consumption (BSFC) at 25% load compared with pure diesel.
- The B30GNP50 shows % reductions in HC, CO_2, NOx, and smoke of 36.36%, 7.41%, 35.29%, and 10.34%, respectively, compared to pure diesel.
- The ANN approach considers two performance parameters, BTE and BSFC, as input variables. Overall regression coefficient measure goodness of fit of regression model. It varies between 0-1. The overall regression coefficient for validation, training, and testing in the trained network is 0.9971, 0.99795, 0.99704, and 0.99259, respectively. The mean absolute percentage error value obtained from the considered model is 2.433%. Comparative studies show that BTE increases as the load increases, suggesting improved engine performance and efficiency

CONCLUSION

The present research work focused on the investigation of performance characteristics of soybean biodiesel with GNP under different concentrations, loads, and blend ratios. Graphene nanoparticles (GNP) introduction to soybean biodiesel has improved diesel engine performance. The B30GNP50 blend showed the best results, with higher brake thermal efficiency. The lower fuel consumption also confirmed that nanoparticles can burn fuel more efficiently.

The study found that nanoparticles blended biodiesel significantly reduced harmful emissions from diesel engines. The B30GNP50 blend is especially effective, lowering carbon monoxide (CO), Nitrogen oxide (NOx), and unburned hydrocarbon (HC). These Graphene nanoparticles and biodiesel reduced the environmental impact of diesel engines.

This research created and validated mathematical and artificial neural network models to predict engine performance and emissions. These models provide highly accurate, with strong

regressions coefficients and low mean absolute percentage error (MAPE). The model provides valuable tools for optimizing blend compositions in future research and application.
B30GNP50 blend was found to be the best blend as it improved engine performance and reduced emissions. It achieved high efficiency and reduced pollutants proving graphene nanoparticles an effective and sustainable biodiesel additive.

FUTURE SCOPE

The research on the use of organic NPs and hybrid as nano-additives in diesel/biodiesel fuels is lagging in contrast to the metallic, non-metallic nanoparticles. Nanoparticle stability and long storage in liquid fuel are also important. Stability analysis may be done by altering nanoparticle surfaces using surfactants and dispersants. A further scope of microscopic research on superficial and inter-facial effects, the nanoparticle motion, and the interactions between the static and flow conditions inside engine.

ORGANIZATION OF THE THESIS

The chapter are arranged according to the methodical research that has been carried out during the experiment. This thesis includes the following chapters.
Chapter 1 Introduction: Which introduce and explain about research work with basic definition and keywords related to research. It describes the need of alternative fuels for dimensioning the alternate fuels.
Chapter 2 Literature Review: This chapter deals past experimental studies carried on nano fuel charge diesel engine and related to inclusion of various dosages of nanoparticles to diesel fuel. Based on the research gap identified from the literature, the specific objectives are framed and listed at the end of the Chapter.
Chapter 3 Materials and Methods: The materials and methods for executing various sets of experiments discussed in this chapter. It includes the steps involved in the preparation of various samples, dosages of nanoparticles and also various test-fuels for investigations.
Chapter 4 Experimental setup and Methodology: This chapter details the experimental setup and methodology employed for various experiments for performance, emission, and combustion analysis. It covers the specifications of all the instruments used during experiments. It also includes the research methodology followed for conducting experiments.

Chapter 5 Results and discussions: This section details the results and discussion, including graphical representations of performance features such as BTE and BSFC, as well as engine exhaust emissions (NO_X, smoke opacity, HC, CO, CO_2).

Chapter 6 Conclusion and future scope: The last section summarizes the experimental and numerical analysis of the proposed research work. It outlines the overall research findings, future challenges, and future scope of work.

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1.Kadam P.M., Dolas D. R. “Study of CI Engine Performance and Emission Evaluation For Soybean Biofuel With Varying Cerium Oxide Concentrations” African Journal Of Biological Science Volume 6, Issue Si3, June 2024 DOI 10.48047/AFJBS.6. Si3. 2024.1819-1831.

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3.Kadam P M, Dolas D.R. “Performance and emission characteristics evaluation of Graphene Nanoplatelets (GNP) additives-based soybean and diesel fuel for a compression ignition engine under varying loads.” International Journal of Automotive Science and technology E-ISSN 2587-0963 (Under review)

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1. Kadam P M, Dolas D R, Bhusare H.S “Review on Performance Characteristics of The Diesel Engine and Use of Nanoparticle.” AICTE Sponsored Springer International Conference on Recent Evaluation in Energy, drives and e-Vehicles. Organized by St Vincent Pallotti College of engineering & Technology, Nagpur. September 16-17 2022.
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3. Kadam P. M., Dolas D. R. “Characteristics and performance analysis for Diesel Engines using Cerium Oxide (CeO_2) Nanoparticles Blended with Biodiesel” An International Conference On recent advances in materials, manufacturing and machine Learning. Yashwantrao Chavan College OF Engineering Nagpur. 2-4 February 2023.
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5. Kadam P. M., Dolas D.R. “An Overview of the effects of nanofluid additives on the emissions and performance of CI engines for diesel and biodiesel blends.”1st International Conference on New Frontiers In material for Engineering Application Ballari Institute of engineering and technology. 26-27 July 2024.

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